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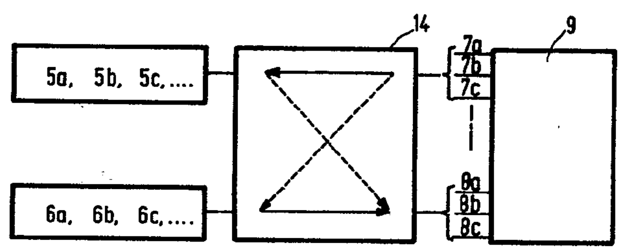
(71) Applicant: **North American Philips Corporation, 100 East 42nd Street 9th Floor, New York, N.Y. 10017 (US)**

(72) Inventor: **'t Hoen, Pieter, c/o INT. OCTROOIBUREAU B.V. Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL)**

(74) Representative: **Veenstra, Gustaaf et al, INTERNATIONAAL OCTROOIBUREAU B.V. Prof. Holstlaan 6, NL-5656 AA Eindhoven (NL)**

(54) **Phased array for ultrasonic medical imaging.**

(57) A bi-plane phased array for real time medical imaging comprises a composite piezoelectric disk (3) with an array of transducer-element electrodes (5a, 5b, 5c, . . . 6a, 6b, 6c, . . .) disposed on each major surface (1, 2) of said disk, the array on one side being at an angle to the array on the other side and switching means (14) to ground each array alternately so that real time sector imaging in two planes is obtained.



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Phased array for ultrasonic medical imaging.

The invention relates to a phased array for ultrasonic medical imaging comprising :

a plate of piezoelectric material having two major surfaces,

a plurality of adjacent electrodes disposed on each of said two major surfaces, those electrodes on a first surface being at an angle to those electrodes on the second surface, the area of the disk underlying each of the electrodes defining a separate transducer element, and switching means to selectively connect the transducer elements with phased-array electronics.

In the technology of medical imaging with ultrasound, the phased array principle is well known, though the technical terminology can be semantically misleading. For the purposes of this application, the following definitions will be used. A linear array is an electronically scanned linear array of elements, that is, a group of contiguous transducer elements which are electronically selected from an extended array, being pulsed for transmission and then used for reception of resultant echoes. The selected group is then commutated one or more positions along the array and the process repeated to scan successive parallel regions in the body. The image format is usually rectangular.

A phased array refers to a short array of elements, the transmitted energy being deflected from the normal by inserting delays in the pulse signal to each element and similarly the received response is steered in angle by inserting delays in the signal path from each angle before summation. The resulting image is pie-shaped, the so-called sector scan.

Electronic focusing of both types of arrays is possible by a different set of time delays.

The use of bi-plane transducer elements in rectangular arrays is known in the prior art. Typical of the prior art are the devices disclosed in U.S. Patent Nos. 4,112,411 and 4,324,142. However, the mosaic of transducers disclosed in these prior patents cannot be used in a bi -plane phased array. Neither of these prior patents discloses means that permit the real time imaging of two sector planes which can be at any angle, e.g. orthogonal.

It is an object of the present invention to extend the phased array principle to the imaging of two planes in real time, a technique which can be of value in certain medical application, for example, for evaluating the dynamics of the human heart. To achieve this purpose, the phased array according to the present invention is characterized in that the plate of piezoelectric material consists of

a flat disc of a composite piezoelectric material, said composite material having cylinders of a piezoelectric material each cylinder extending from one major surface of said disk to the other major surface of said disk perpendicular to the diameter of said disk, each of said cylinders being completely surroundedby an insulating damping material and in that the switching means comprise means to connect alternately all transducer elements on one electrode surface with the phased-array electronics while grounding the transducer elements on the other electrode surface to effect a sector scan in each of two planes, such that an image in one direction is followed by an image in a second direction.

The disc is made of a composite piezoelectric material because a material with negligible cross-coupling must be utilized in the fabrication of the proposed bi-plane phased array in order to make the cross-bar electrode pattern possible. The material is classified as composite because it is or may be basically a laminated structure in which a plurality of relatively small

parallel cylinders of a piezoelectric ceramic material are aligned with the acoustic axis of the transducer, perpendicular to the major surfaces, and are completely surrounded by an electrically insulating and acoustically damping material. Such a composite material will have negligible cross-coupling, which is necessary for a plurality of transducer elements in close proximity to one another. The bi-plane phased array can be fabricated by putting an electrode surface on each major surface of a slice of the composite material and scoring the electrode surfaces such that the scoring on one side is at an angle with the scoring on the otherside.

Appropriate electrical connections are made such that all the electrode elements on one electrode surface are grounded, and phasing is performed with the remaining free electrodes to image, according to the phased array principle, in one direction, and alternately all electrode elements on the other electrode surface are groundes so that phasing is performed with the free electrodes on the first side to image in a second direction. In a preferred embodiment the array of transducers is capped on one side by a mechanical lens.

Figure 1 is a perspective view of a composite piezoelectric disc from which the bi-plane phased array is made;

Figure 2 is a cross-section taken along the line A-A of Figure 1 showing a convex spherical mechanical lens in place over one major surface of the composite piezoelectric disk;

Figure 3 is a top view of the composite piezoelectric disk showing the electrode pattern configuration of one major surface. The electrode configuration on the other major surface is shown by dotted lines.

Figure 4 is a functional diagram of the basic electronic configuration for use with bi-plane phased array of the present invention.

Figure 5 is a cross-section view of the composite

piezoelectric disk before scoring of the electrode configurations.

As shown in Figures 1 through 3 and 5, the bi-plane phased array of the present invention comprises a flat piezoelectric disk 3, the disk shape being used for simplification of electrical connections and to secure good focusing in all directions, fabricated from a composite material, shown in detail in Figure 5, which comprises a matrix of parallel cylinders 10 of a piezoelectric ceramic material, distributed in an electrically inert binding material such that each cylinder is completely surrounded by the insulating, damping material 12, said rods extending from one major surface 1 of the disk to the other major surface 2 perpendicular to the diameter of the disk, each major surface having an electrode surface and each electrode surface being scored, as shown in Figure 3, such that the front electrode surface 1 is scored at an angle different from the scoring of the back electrode 2.

Examples of materials of this type are disclosed in U.S. Patent No. 4,514,247 and U.S. Patent No. 4,518,889. The lateral spatial periodicity of the composite piezoelectric structure is smaller than all the relevant acoustic wavelengths. Hence the composite behaves as a homogeneous piezoelectric with improved effective material parameters, as discussed in the art cited above. One of the electrode surfaces 1 is designated the front face, the other electrode surface 2 being designated the back face. When used in an ultrasonic transducer for medical imaging, the front face 1 is the face which is placed toward the body of the patient.

Figure 2 is a cross-section taken along the line A-A of Figure 1 of the composite piezoelectric disk showing a convex spherical mechanical lens 4 in place over the front face 1 of disc 3. This permits mechanical focusing in all directions to be utilized.

Figure 3 illustrates a top view of the electrode pattern configuration of the composite piezoelectric disk

used in the transducers of the present invention. The front electrode transducer elements 5a, 5b, 5c,... are obtained by cutting through the electrode surface 1. The back electrode transducer elements 6a, 6b, 6c, ... shown by dotted lines in Figure 3, are cut through the back electrode 2 at an angle to the lines defining the front electrodes. The electrodes of the composite piezoelectric material are scratched through the conductive layer rather than diced through the piezoelectric material on both sides of the piezoelectric disk. While the angle shown in the drawing is 90°, other angles may be utilized.

Figure 4 is a diagrammatic representation of the basic configuration for the electronics required for the bi-plane phased array. In this figure, the reference numeral 9 designates the phased array electronics for transmitting, receiving, steering and focusing. Switching means 14 are provided to alternately connect the front face elements 5a, 5b, 5c ... and the back face elements 6a, 6b, 6c ... to the transmission lines 7a, 7b, 7c ... for the signal and the signal return lines 8a, 8b, 8c ..., the elements on the opposite face being grounded.

The phased array circuits 9 provide the means to pulse alternately all transducer elements on one electrode surface, while the transducer elements on the other electrode surface are grounded to effect a sector scan in two planes, alternately, such that an image in ione direction is followed quickly by an image in a second direction, thus producing a dynamic image of a bodily function. Such circuits are known in the art.

For n electrodes on each major surface, thus a total of 2n electrodes, 2 n electrical connections are required for the bi-plane phased array of this invention. In contrast, the prior art mosaic electrode patterns require n^2 connections for n electrodes.

The bi-plane phased array, using both major surfaces of a composite piezoelectric disk, permits the

real time imaging of two sector planes. This bi-plane approach is particularly of value for real time evaluation of cross-sections of the heart.

The area of the composite piezoelectric disk 3 underlying each of the electrodes defines a separate transducer element. In operation, either the front electrodes 5a, 5b, 5c, ... or the back electrodes 6a, 6b, 6c, ... are grounded and the phasing is performed with the remaining free electrodes. The spherical mechanical lens 4 secures focusing in the other direction. Since no dicing is used and negligible cross-coupling is mandatory, composite piezoelectric material is used.

The mechanical lens 4 of the present invention is a relatively standard lens which is made from a material with a rather low US propagation velocity. But the acoustical impedance should not be very different from the skin acoustical impedance, to suppress reverberation.

1. A phased array for ultrasonic medical imaging comprising:

a plate of piezoelectric material having two major surfaces,

a plurality of adjacent electrodes disposed on each of said two major surfaces, those electrodes on a first surface being at an angle to those electrodes on the second surface, the area of the disk underlying each of the electrodes defining a separate transducer element, and

switching means to selectively connect the transducer elements with phased-array electronics, characterized in that the plate of piezoelectric material consists of

a flat disc of a composite piezoelectric material, said composite matérial having cylinders of a piezoelectric material each cylinder extending from one major surface of said disk to the other major surface of said disk perpendicular to the diameter of said disk, each of said cylinders being completely surrounded by an insulating damping material

and in that the switching means comprise means to connect alternately all transducer elements on one electrode surface with the phased-array electronics while grounding the transducer elements on the other electrode surface to effect a sector scan in each of two planes, such that an image in one direction is followed by an image in a second direction.

2. A phased array as claimed in Claim 1, characterized in that the plate of piezoelectric material comprises

a mechanical lens over one electrode surface.

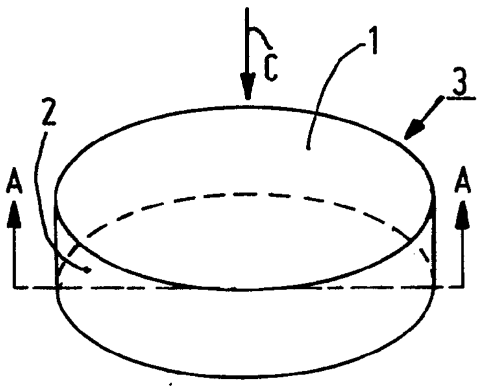

FIG.1

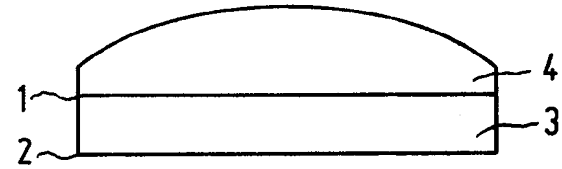

FIG. 2

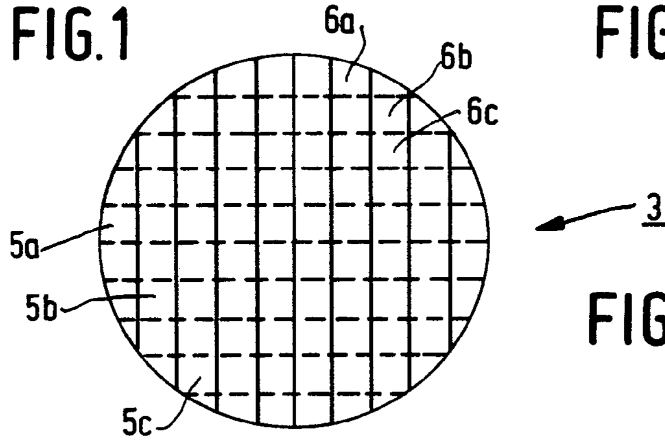

FIG. 3

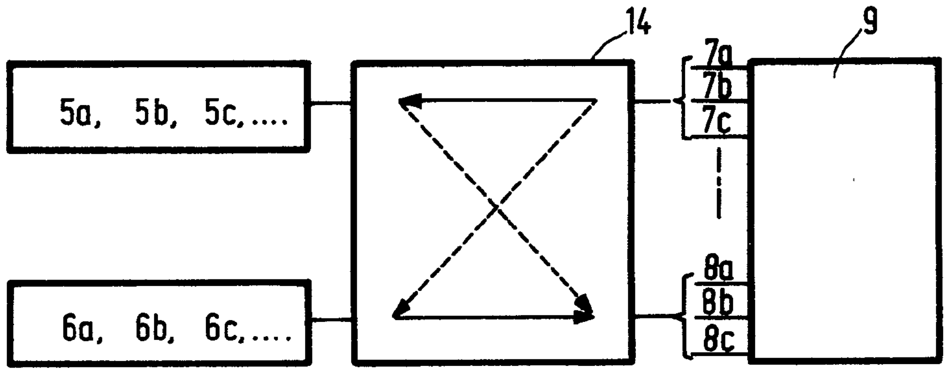

FIG. 4

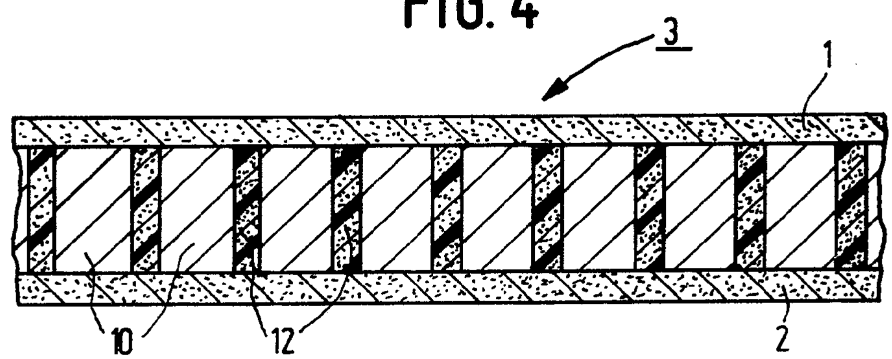

FIG. 5

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EUROPEAN SEARCH REPORT

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DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
X	DE-A-3 219 229 (SIEMENS) * Abstract; claims 1,2,4,7,8; page 5, line 24 - page 6, line 15; page 7, line 16 - page 9, line 29; figures *	1	G 01 S 15/89 G 01 S 7/62 G 10 K 11/34
X	EP-A-0 041 664 (SIEMENS) * Abstract; page 3, line 15 - page 7, line 27; page 8, line 30 - page 11, line 15; claims 1,2 *	1	
A	US-A-4 122 725 (THOMPSON) * Abstract; column 2, line 24 - column 3, line 15; column 3, line 46 - column 6, line 55 *	1	
A	US-A-2 832 058 (SAMSEL) * Column 1, line 46 - column 2, line 54; column 3, lines 5-10 *	1,2	**TECHNICAL FIELDS SEARCHED (Int. Cl.4)**
A	DE-A-2 946 485 (GESELLSCHAFT FÜR STRAHLEN- UND UMWELT-FORSCHUNG) * Claims 1-3; page 5, lines 3-18; figure 2 *	1	G 01 S G 10 K B 06 B
A	GB-A-2 075 797 (TOSHIBA) * Abstract; page 1, line 98 - page 2, line 69; page 2, line 113 - page 3, line 16; page 3, line 118 - page 4, line 27 *	1	
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	22-09-1986	OLDROYD D.L.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
A	US-A-4 131 024 (MEZRICH et al.) * Column 2, line 32 - column 3, line 56 *	1	

			TECHNICAL FIELDS SEARCHED (Int. Cl.4)

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THE HAGUE	22-09-1986	OLDROYD D.L.

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